An Image-based Anisotropic Reflection Modeling of Textile Fabrics based on the Extended KES method

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1 Introduction

One of the most challenging problems in computer vision and computer graphics is a modeling of deformable objects with anisotropic reflection properties such as textile fabrics. In this paper, we propose an efficient image-based anisotropic reflection modeling method of textile fabrics based the microfacet surface geometry determined by the cross-section shape of fibers, twist of strings, and a type of weave. We first examine the relationship between the reflectance properties and the microfacet surface geometry of a textile fabric using a silk-like synthesized fabric. We then develop an anisotropic model, which provides a bi-directional reflectance distribution function (BRDF) from small numbers of images observing the orthogonal characteristics of textile fabrics, based KES(Kawabata's Evaluation system for fabrics) method. Experimental results show the efficiency and effectiveness of the proposed approach.

2 Anisotropic Reflection Modeling based on the extended KES

Fabric industry use Kawabata's Evaluation System for Fabric (KES) as the method to measure dynamic characteristics of fabric such as tensile or a bending properties. Originally, KES was developed for quantization of fabric texture from properties of warp and weft. Sakaguchi [1] extended KES so that it could take properties in bias directions.

A fabric differs depending on its material, we need enormous number of measurement (combination of incident direction and viewing direction) in order to get a BRDF with high resolution. However, we can limit the directions of measurement only from four directions , since 1) a fabric has orthogonal bi-directional anisotropy and a string has unidirectional anisotropy and 2) measurements among the four directions is enough as long as the orthogonal anisotropy of a fabric can be interpolated by the extended KES.

Thus, we measure the objective fabric only from four directions by rotating it by $\frac{\pi}{4}$ degrees at each time.

Figure 1 shows our omnidirectional optical gyro measuring machine (OGM) of 4 DOF.

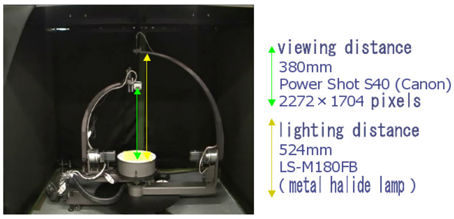
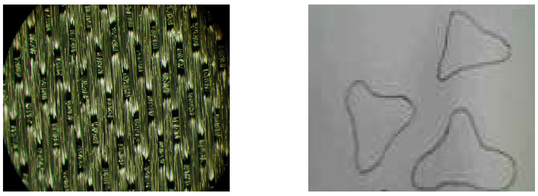


Figure : OGM(Optical Gyro Measuring machine)

The objective fabric is a black satin cloth, a weave and a fiber's cross-section shape of which are shown in Fig2.(a) and (b).

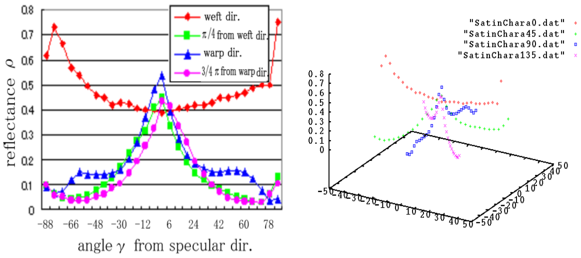


(a) Satin weave (b) Cross-Section of a warp fiber

Figure2 : Weave and a warp fiber of a black satin

STEP1. Reflection Measuring in Warp , Weft , $\frac{\Pi}{4}$ and $\frac{3}{4}\Pi$ Bias Directions

We measured brightness of reflected ray by changing the direction of incident ray from $\frac{\Pi}{2}$ to 0 and the viewing angle from 0 to $\frac{\Pi}{2}$ at every 3 degrees. The same measurement was done in the warp, weft, $\frac{\pi}{4}$ and $\frac{3}{4}\pi$ bias directions and we obtained total 116 set of BRDF values. Figure 3(a) and (b) shows reflectance values measured along $0, \frac{\pi}{4}, \frac{\pi}{2}, \frac{3}{4}\pi$ directions.



(a)ρ *v.s.*γ (b)3D representation

Figure3 : Reflectance ρ v.s. an angle γ from the direction of specular reflection

STEP2. Interpolating Anisotropic Reflection with the extended KES method

We interpolate reflectance properties from the 4 directional measurements using the extended KES[1]. In the extended KES, dynamic properties is given by the following equations (1) and (2).

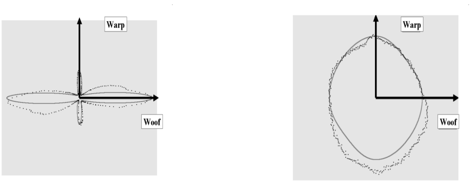
$$\rho_{KES}(\phi,\gamma)$$
$$= \left\{ \frac{cos^4\phi}{\rho(0,\gamma)} + G' sin^2\phi cos^2\phi + \frac{sin^4\phi}{\rho(\frac{\pi}{2},\gamma)} \right\}^{-1} \quad (1)$$

$$G' = \frac{4}{\rho(\frac{\pi}{4},\gamma)} - \frac{1}{\rho(0,\gamma)} - \frac{1}{\rho(\frac{\pi}{2},\gamma)} \quad (2)$$

where $\rho(0,\gamma), \rho(\frac{\pi}{2},\gamma)$ and $\rho(\frac{\pi}{4},\gamma)$ are dynamic properties in the warp, weft and $\frac{\pi}{4}$ bias direction such as tensile and bending properties , ϕ is an angle against the weft direction, γ is force.

For each γ, an angle from the direction of specular reflection, we obtain reflectance of $\rho(0,\gamma)$, $\rho(\frac{\pi}{4},\gamma)$, $\rho(\frac{\pi}{2},\gamma)$, $\rho(\frac{3}{4}\pi,\gamma)$. These values correspond to the four points on the vertical line in Figure 3(a). Then using equations (1) and (2), we interpolate the reflectance $\rho(\phi,\gamma)$ in a certain direction ϕ. Figure 4 shows the comparison between the KES interpolation values (a solid curve) and measured values(a dashed curve) at $\gamma = -\frac{\pi}{3}, 0$, respectively.

These results show the efficiency in reflectance interpolation by the extended KES method.



(a)$\gamma = -\frac{\pi}{3}$ (b)$\gamma = 0$

Figure4: Measured(dashed) v.s. KES interpolated values(solid) of reflectance

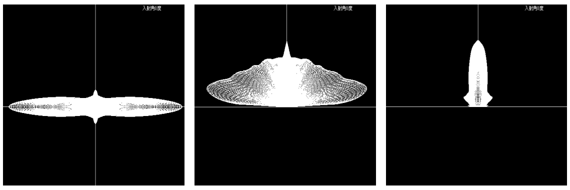
STEP3. Genrating an Anisotropic Reflection Model

Figure 4 is the spherical representation of reflectance curves of the same γ, where x, y and z axis represents the the direction of warp, weft and specular reflection and a radias $\rho(\phi,\gamma)$ represents the reflectance. We call this graph as the anisotropic reflection model. The BRDF will be then obtained by the following equation.

$$BRDF(\theta_r,\phi_r,\theta_i,\phi_i) = \frac{1}{\sqrt{\cos\theta_i \cos\theta_r}} \frac{1}{\sin\beta}$$
$$*\rho_{KES}(\frac{\pi}{2} - (\phi_i + \phi_r), \theta_r - \theta_i) \quad (3)$$

$$\sin\frac{\beta}{2} = \frac{1}{2}\sqrt{\sin^2\{\phi_r - (\phi_i + \pi)\} + \cos^2\theta_r} \quad (4)$$

where (θ_r, ϕ_r) is the reflection(viewing) direction, (θ_i, ϕ_i) is the incident ray direction, and θ and ϕ is an angle against the directions of welf and the specular reflection , respectively.



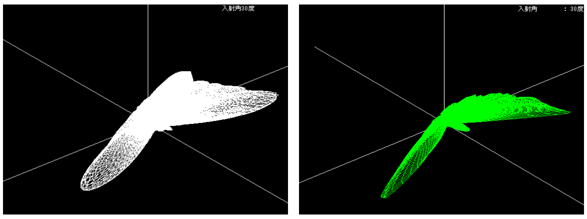
(a)x=welf and y=a warp plane (b)x=welf and y=a specular dir. (c)x=warp and y=a specular dir.

Figure5: Anistropic reflection model(spherical coord).

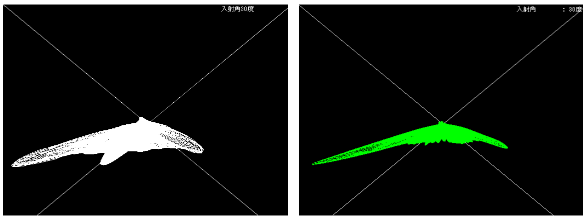
STEP4. Evaluating Our Model

We compared the simulated reflection values of the satin cloth by our model with the real reflection values, measured by OGM.

Figures 6(a)(b) show the comparison results by the incident ray, of $(\theta_i = \frac{\pi}{6}, \phi_i = \frac{\pi}{2})$ and $(\theta_i = \frac{\pi}{6}, \phi_i = \frac{\pi}{4})$, respectively.



(a)simulated(left) and real(right) reflectance at $(\theta_i = \frac{\pi}{6}, \phi_i = \frac{\pi}{2})$



(b)simulated(left) and real(right) reflectance at $(\theta_i = \frac{\pi}{6}, \phi_i = \frac{\pi}{4})$

Figure6: Simulated v.s. real reflectance of a satin cloth.

We confirmed that our method can effectively generates an accurate BRDF of a fablic through the experiments. Our model is applied to dressing simulation of arbitrarily colored satin. An attached democlip shows the performance of our model.

Reference

[1] Y. sakaguchi, et.al, "An Numerical Calculation Method for a Dynamically Deformable Cloth model, " Trans. of IEICE J77-D-Ⅱ, vol.5, pp.912-921(1994) (In Japanese)